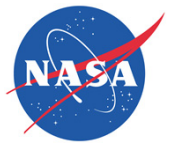

Spacecraft-to-Earth Communications for Juno and Mars Science Laboratory Critical Events

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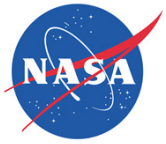
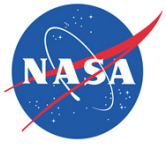


Outline

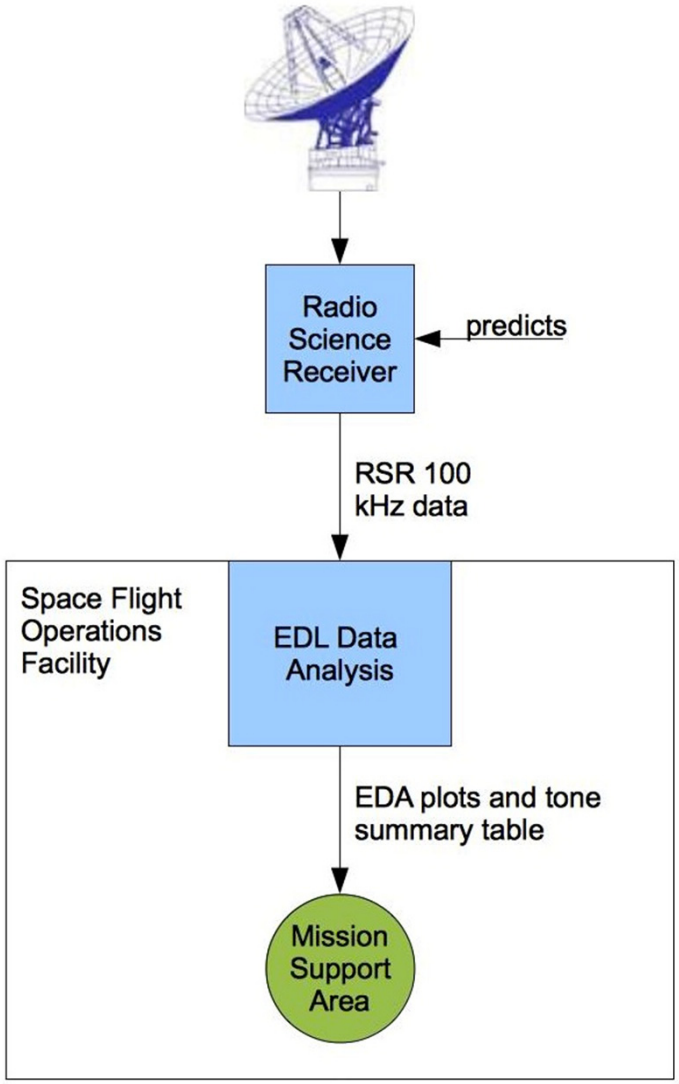
- Introduction
- System Design
- Juno
- Juno Tones Tests
- Simulations of Juno JOI
- Mars Science Laboratory
- MSL Test Bed Tones tests
- Simulations of MSL EDL
- Conclusions



Introduction

- Deep Space communications typically utilize closed loop receivers and Binary Phase Shift Keying (BPSK) or Quadrature Phase Shift Keying (QPSK)
- Critical spacecraft events include orbit insertion and entry, descent, and landing
  - Low gain antennas -> low signal-to-noise-ratio
  - High dynamics such as parachute deployment or spin -> Doppler shift
- During critical events, open loop receivers and Multiple Frequency Shift Keying (MFSK) used
- Entry, Descent, Landing (EDL) Data Analysis (EDA) system detects tones in real-time

System Design



System Design

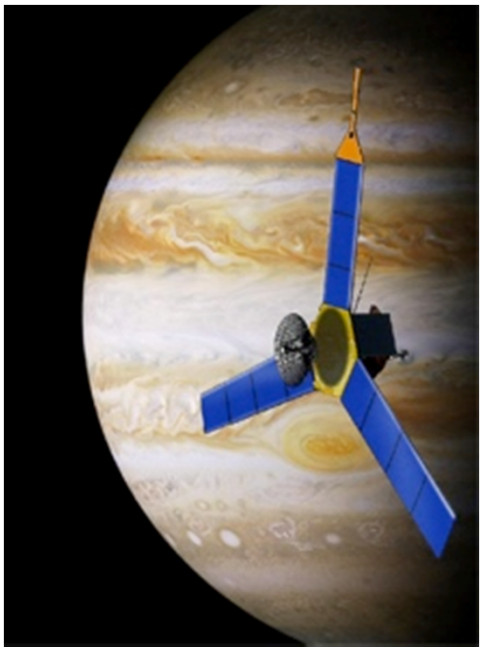
- Tone detection is accomplished using an FFT-based frequency and frequency rate loop on the carrier
- Each critical event is divided into time segments with different signal dynamics: cruise, entry, parachute deployment, bridle and bouncing, landing
- Real time- maximum performance with minimum latency
- 4 EDA systems:
  - 2 for MSL
  - 2 for Juno

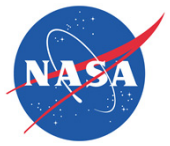
Juno

- Launched August 5, 2011
- Cruise time to Jupiter is about 5 years
- Uses an Earth-Gravity-Assist that relies on deep space maneuvers about a year after launch
- Torroidal Low Gain Antenna used for critical maneuvers

Table 1- Planned dates of Juno EDA Usage

Event	Date
Tones Tests	September 7, 2011
Deep Space Maneuvers	September 2012
Jupiter Orbit Insertion	July 4-5, 2016
Period Reduction Maneuver	October/November 2016





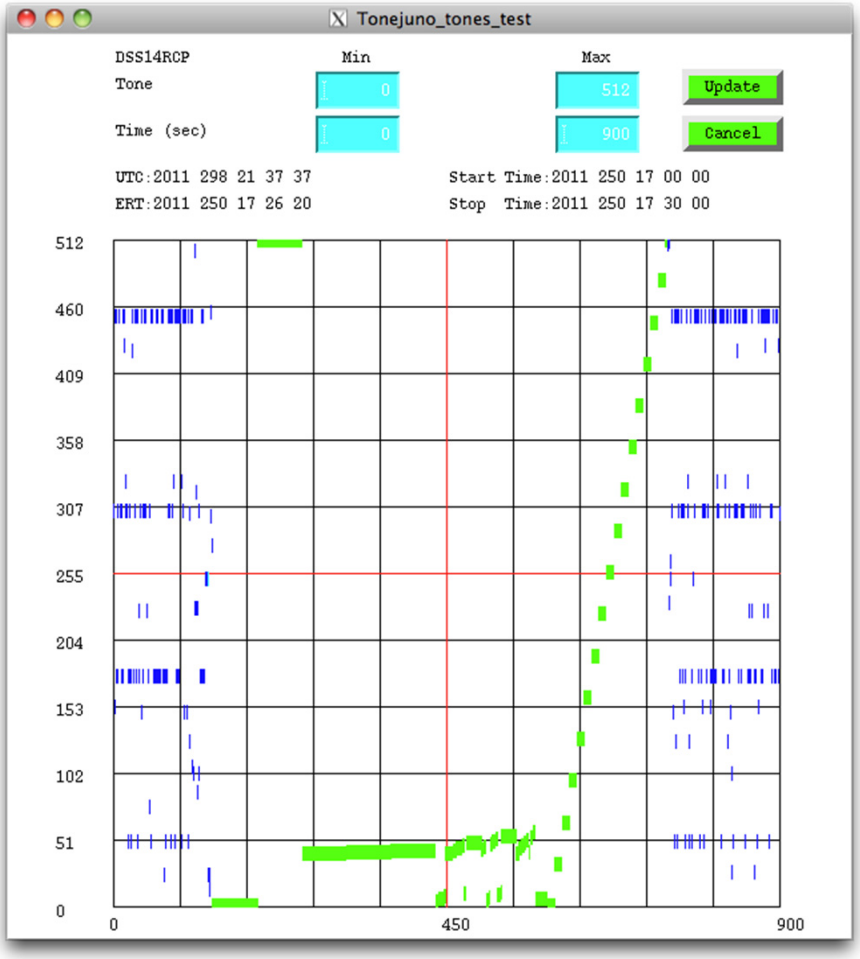
Juno Tones Tests

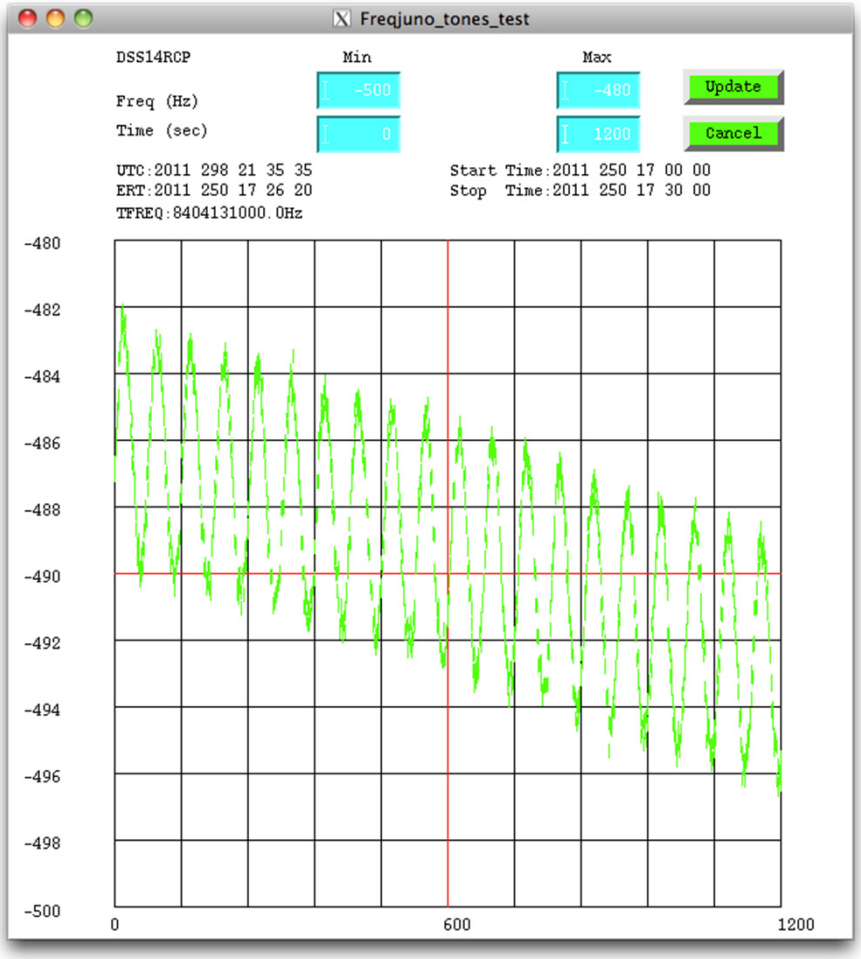
- In-flight tones test took place on September 7, 2011
- Tones may be high or low priority
- High priority tones must be >= 3 sec in duration
- Tones test sequence included 4 cases:
  - Basic Tones: complete range of 1-512, adjacent frequencies
  - Prioritization: high and low priority tones in rapid succession
  - Sustained Sequence: 10 tones, each emitted for 3 seconds
  - Flurry of Tones: mix of high and low priority tones
- Three tests took place:
  - A: DSS-14
  - B: DSS-14 and DSS-43
  - C: DSS-43

Juno Tones Tests Results

Pc/No of 50 dB-Hz, 1 RPM spin

All tones detected

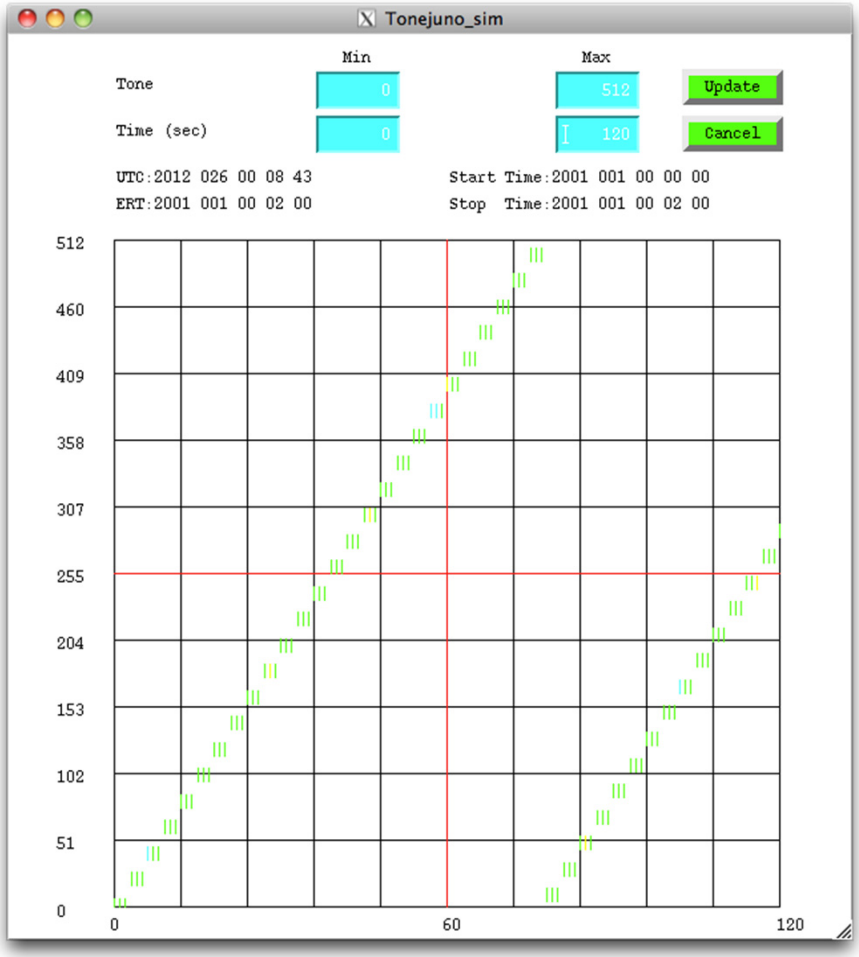




Simulations of Juno JOI

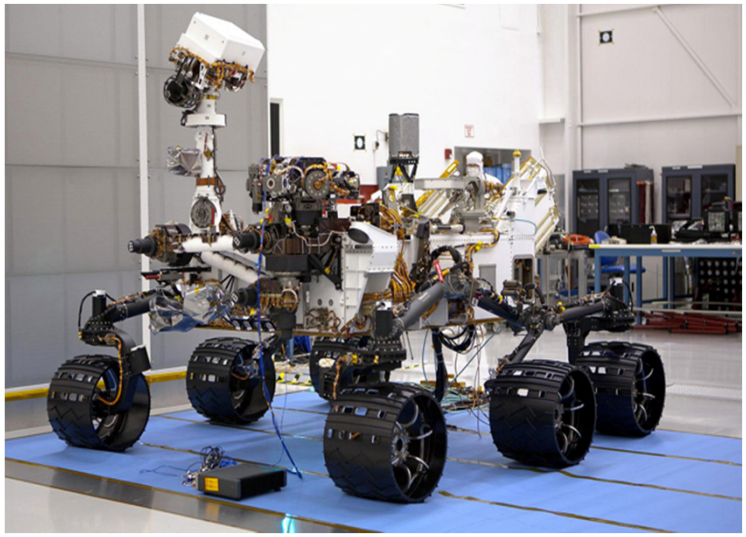
Pc/No of 12-15 dB-Hz, 5 RPM spin expected

>98% of tones detected

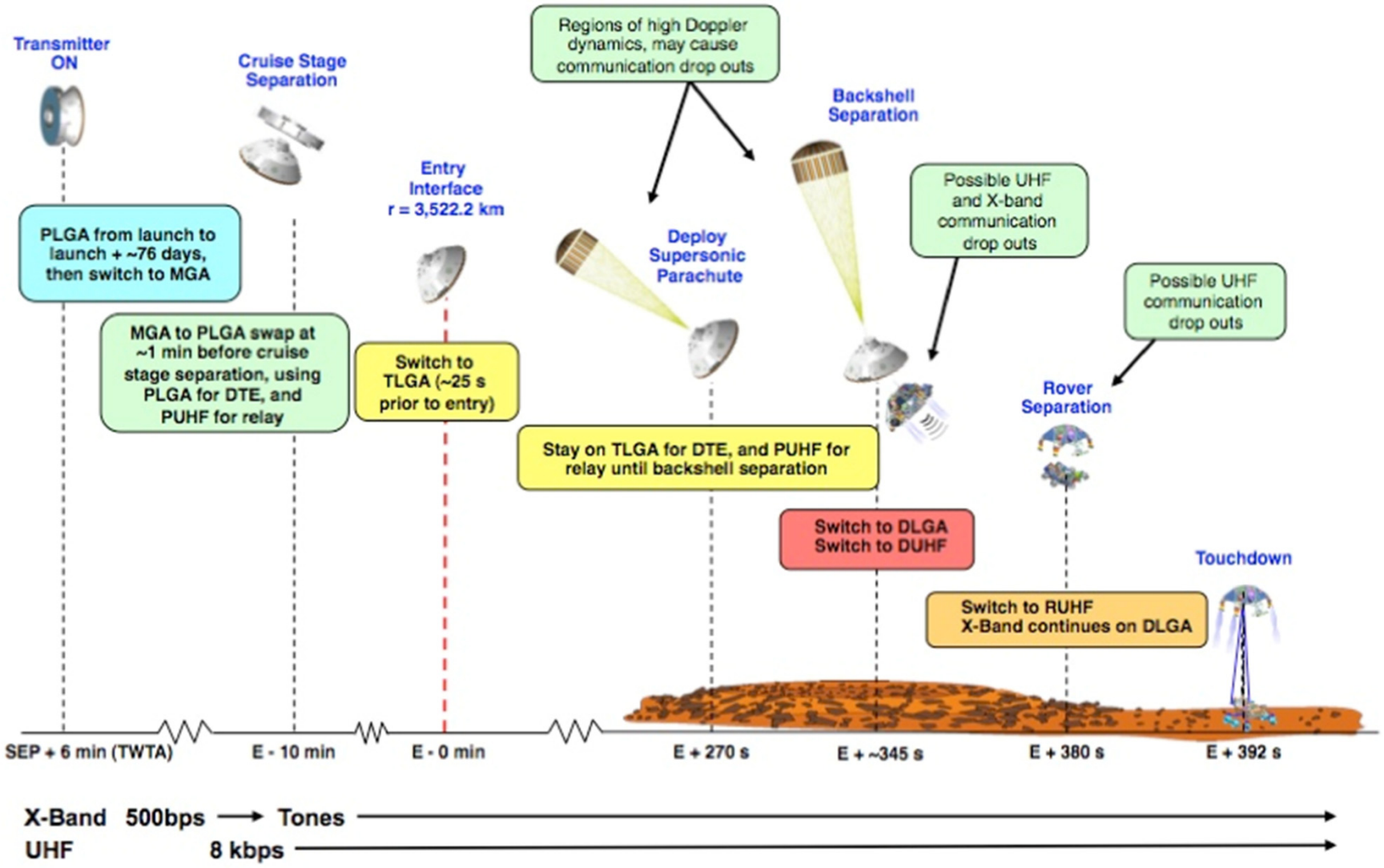


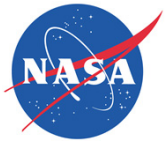
Mars Science Laboratory

- Launched on November 26, 2011
- Entry, Descent, and Landing on Mars on August 5, 2012
- Direct-To-Earth communications during EDL will utilize X-band. Relay communications to Mars Odyssey will utilize UHF.
- UHF communications blackout due to plasma during entry.
- Low gain antennas used:
  - Parachute Low Gain Antenna (PLGA)
  - Titled Low Gain Antenna (TLGA)
  - Descent Low Gain Antenna (DLGA)



Mars Science Laboratory Entry, Descent, and Landing

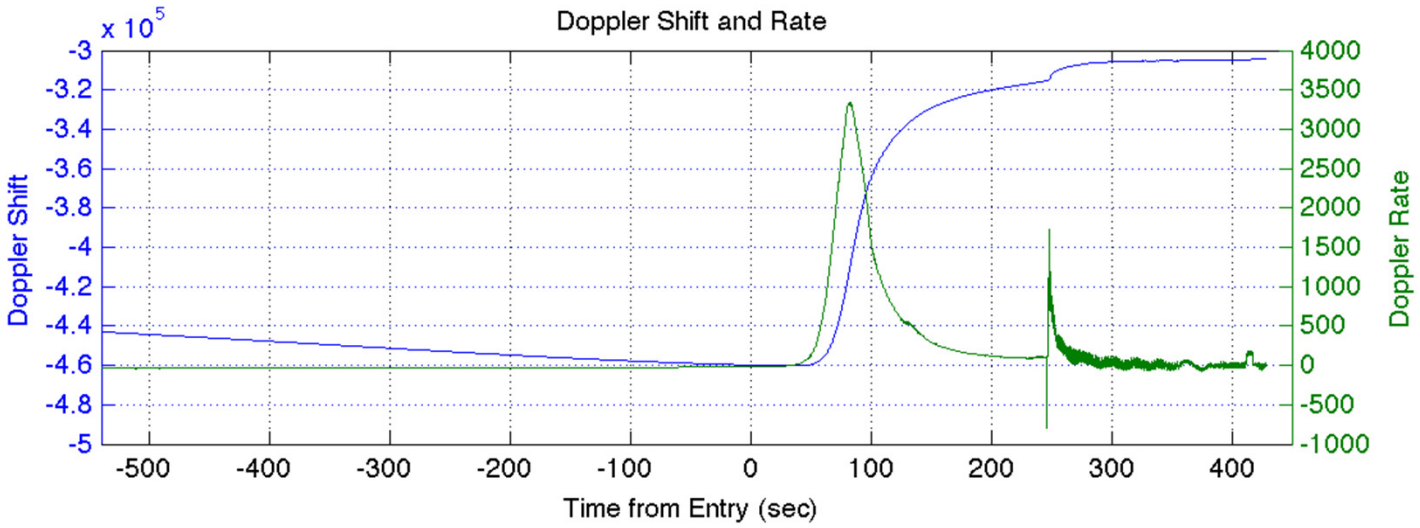


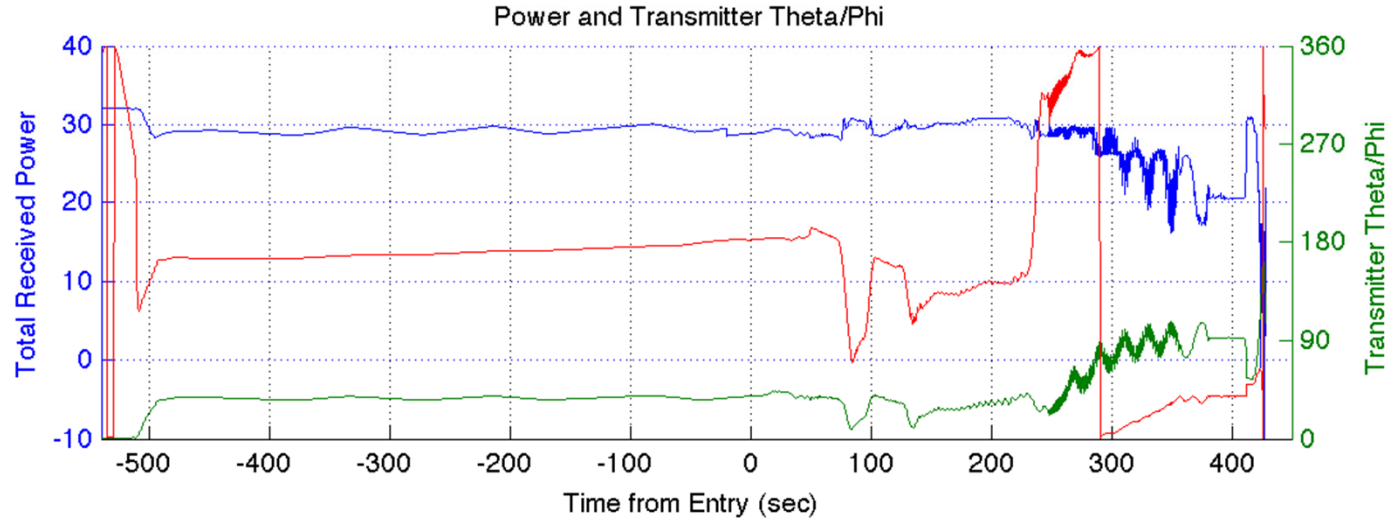


MSL Test Bed Tones Tests

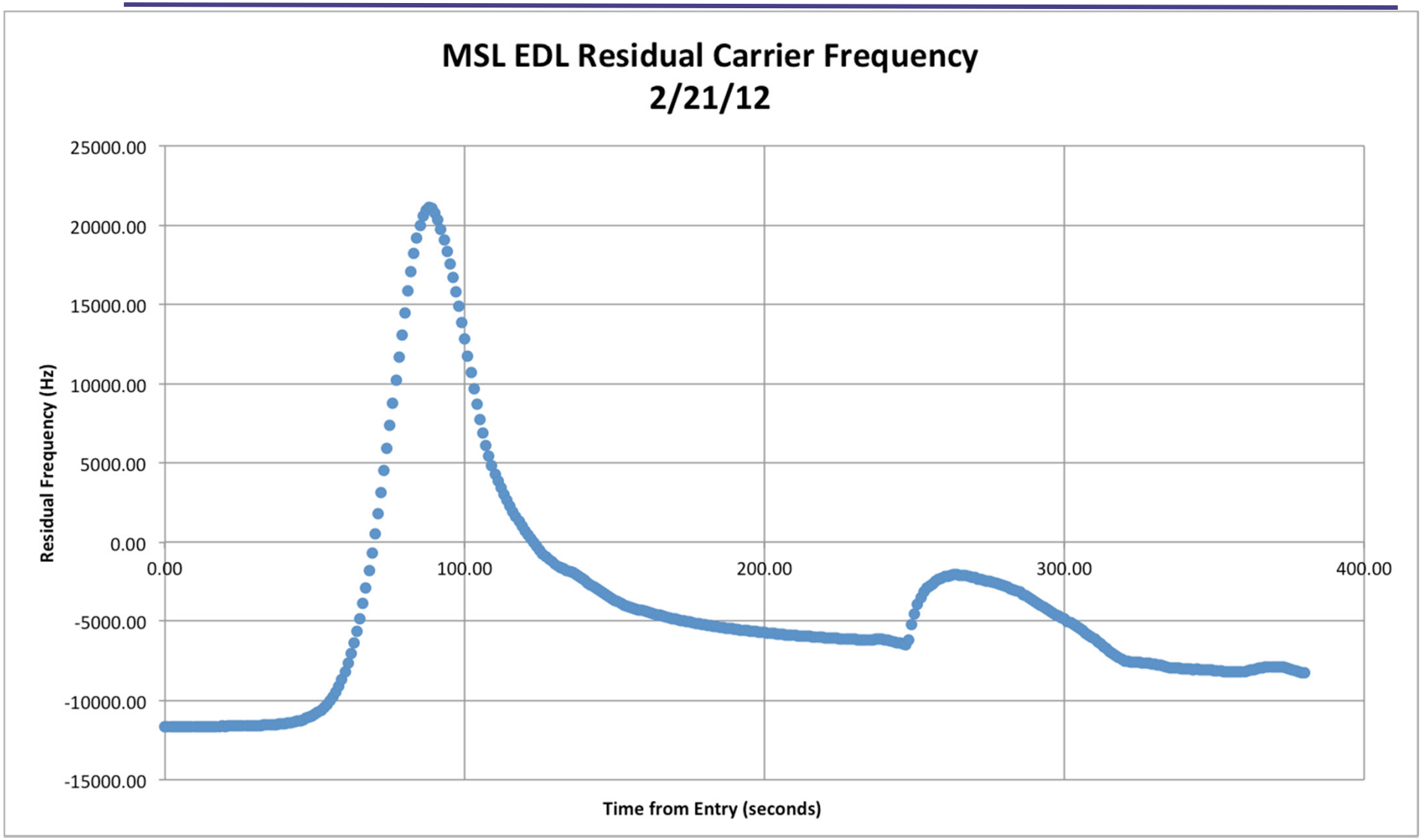
- Fiber link from MSL Test bed to Portable Radio Science Receiver -> EDA
- Four MSL Test Bed tones tests took place in February
  - Nominal case
  - Thermal faults
  - Power Analog Module failure
  - Failure of Guided entry
- All tones detected
- Pc/No as low as 20 dB-Hz but no dynamics

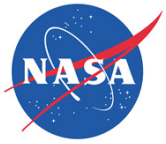
MSL EDL Doppler and Doppler Shift





Simulations of MSL EDL





Conclusions

- EDA software successfully ported to new hardware

- EDA configuration files developed for Juno
- 100% of tones detected in Juno in-flight tones tests
- >98% of tones detected in Juno JOI simulations
- 100% of tones detected in MSL Test Bed tones tests

- EDA configuration files for MSL EDL currently in development